ANTHROPOLOGICAL SCIENCE
Vol. 112, 83-89, 2004

A human parietal fossil found at the Shuidonggou site, Ningxia, China

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Received 17 September 2002; accepted 17 October 2003

Abstract The morphological features of the first human parietal fossil found at the Shuidonggou site of Ningxia, China are described and compared with other specimens. Our results show that most of the features of the Shuidonggou parietal resemble those of modern humans. On the other hand, this specimen was found in situ adjacent to the erosional surface of the late Pleistocene stratum and exhibits a certain degree of fossilization. There are two features which are different from modern humans and similar to those of fossil hominids. One of the features is the strong ridges between the striae parietalis suggesting that the temporalis muscles were more developed than in modern humans. The second feature is the lack of a sigmoid sulcus at the mastoid angle of the Shuidonggou parietal which is similar to the situation seen in *Homo erectus* of Zhoukoudian. Given the similarities of many morphological features between late Pleistocene and modern humans, it is impossible to set the age or evolutionary status of the fossil accurately just from skeletal morphology of a fragmentary parietal. Nevertheless, taking the specimen's fossilization and the background information of the site into consideration, we believe that the parietal likely comes from the late Pleistocene human populations that lived in this area.

Key words: Shuidonggou site, parietal, human fossils

Introduction

The Shuidonggou site is located 38º 21′ north latitude and 106º 29′ east longitude, and its altitude is 1200 meters above sea level. The site is located about 30 km southeast of Yinchuan, the capital of Ningxia Hui Autonomous Region, and 46 km north of Lingwu city (Figure 1). To the north of Shuidonggou is the Great Wall, and a small tributary to the Yellow River occurs to the south. The Shuidonggou site is situated at the west edge of the Ordos plateau. The underlying sequence of pre-Sinian period is covered by Palaeozoic, Mesozoic and Cenozoic sediments.

In 1923, the Shuidonggou site was first found and excavated by Emile Licent and Pierre Teilhard de Chardin. Some mammal fossils, burnt bones and stone artifacts were found (Teilhard de Chardin and Licent, 1924; Boule et al., 1928). Further excavations were carried out by Chinese teams in 1963 and 1980, respectively (Jia et al., 1964; Geological Survey of Ningxia Museum and Ningxia Geological Bureau, 1987). Abundant remains of Upper Paleolithic culture were unearthed from these excavations. Because stone artifacts with Mousterian aspects and blade culture features were found, the Shuidonggou site was considered to correspond to the developed Mousterian to early Aurignacian period of the European Paleolithic culture system, or the late Pleistocene. The Shuidonggou culture represents the latest Initial Upper Paleolithic of Eurasia. Its occurrence predates the emergence of microblade industries in North China, with important implications for human migration or cultural transmission patterns during the late Pleistocene in East

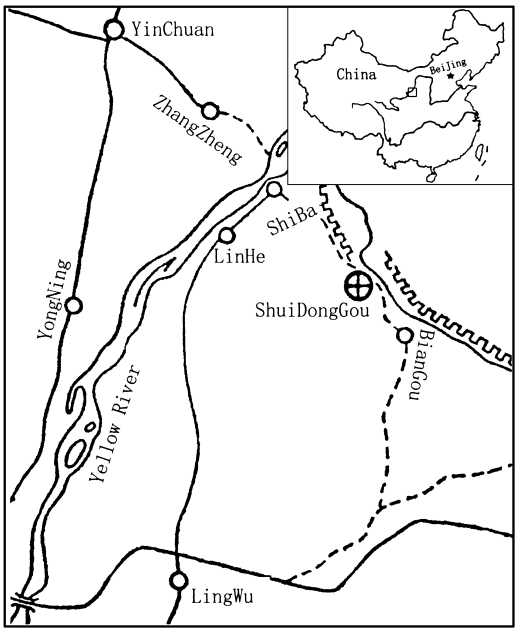

Figure 1. Map showing the geographic position of the Shuidonggou site.

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Published online 16 April 2004
in J-STAGE (www.jstage.jst.go.jp) DOI: 10.1537/ase.00062

Asia.

For the stratigraphy of the Shuidonggou site, several divisions have been proposed (Jia et al, 1964; Geological Survey of Ningxia Museum and Ningxia Geological Bureau, 1987; Zhou et al, 1988). In the present paper, we use the eight-layer division, as given in Geological Survey of Ningxia Museum and Ningxia Geological Bureau (1987), Gao et al. (2002) and Ningxia Institute of Archaeology (2003). According to the depositional sequence defined by this division (Figure 2), the lithic and bone tool findings from strata 1 to 7 are attributed to the Holocene and those from stratum 8 are put into the late Pleistocene (Gao, personal communication). Most of the Shuidonggou stone industry comes from stratum 8 (Geological Survey of Ningxia Museum and Ningxia Geological Bureau, 1987; Madsen et al., 2001; Gao et al., 2002). In the past decades, several radiocarbon dates have been offered for locality 1 (CQRA, 1987; The Institute of Archaeology, CASS, 1991). For stratum 4, two ^{14}C ages of 6.07±0.07 ka and 8.77±0.15 ka were obtained for the upper and lower part of the stratum, respectively, using the corrected half-life of 5730 (if the Libby half-life of 5568 is used, the dates are 5.90±0.07 ka and 8.52±0.15 ka, respectively). The upper and middle to lower parts of stratum 8 were dated to 17.25±0.21 ka and 26.19±0.8 ka, respectively (if the Libby half-life of 5568 is used, the dates are 16.76±0.21 ka and 25.45±0.80 ka, respectively) (CQRA, 1987; The Institute of Archaeology, CASS, 1991). The 17.25 ka date had initially been erroneously attributed to stratum 7 (Brantingham et al., 2001; Madsen et al., 2001), but the sample actually derives from upper stratum 8 (CQRA, 1987; The Institute of Archaeology, CASS, 1991), as given in Gao et al. (2002). Currently, for strata 5 to 7, there are no radiocarbon ages available.

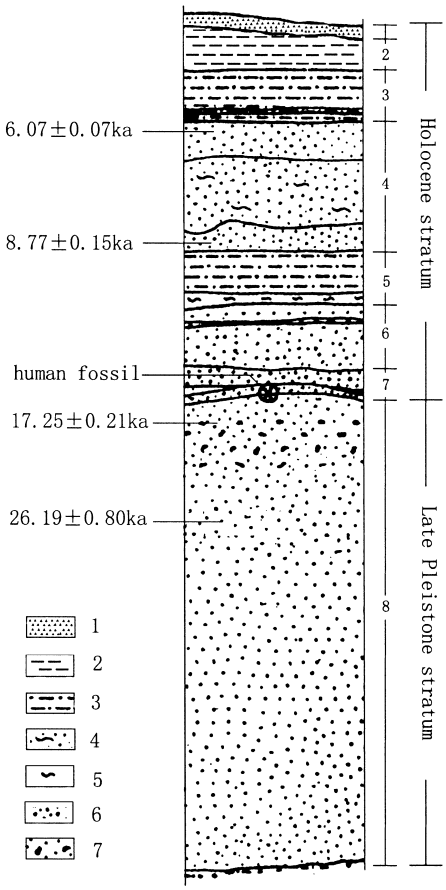

Figure 2. The stratigraphic section of the Shuidonggou site and the locus of the human fossil find. 1, silt; 2, clayey silt; 3, silty clay; 4, carbonaceous clay; 5, clay; 6, sandy debris; 7, carbonate nodules.

In August of 2000, when the staff from the Culture Relic Office of Lingwu city built a ladder road at the Shuidonggou site as a part of the routine procedures of culture relic preservation, a piece of human parietal fossil was found at the bottom of stratum 7 adjacent to the upper border of stratum 8 (Figure 2). The parietal was found just above the erosion surface of the upper part of the late Pleistocene stratum (Figure 2). This is the first human fossil ever found at the Shuidonggou site. As mentioned above, the stratum where the human parietal was found is bracketed by the radiocarbon ages of 8.77±0.15 ka and 17.25±0.21 ka. Given the presence of Upper Paleolithic artifacts and faunal remains of late Pleistocene composition in stratum 8 of the Shuidonggou site (Geological Survey of Ningxia Museum and Ningxia Geological Bureau, 1987; Brantingham et al., 2001), the authors believe that the Shuidonggou parietal fossil likely comes from the late Pleistocene stratum. The present paper describes the anatomical features of the human parietal fossil, and compares it with relevant fossil and modern specimens.

Description of the Fossil

The fossil is yellow in color and no deformation was found. Moderate fossilization can be identified on the fossil. The fossil was separated into two pieces which fit well. The specimen is 95.6 mm in length and 78.9 mm in breadth. After comparisons with human skulls, we identified the parietal found at the Shuidonggou site as the posterior part of the right parietal. The inner surface of the parietal is smooth and blood vessel grooves are easily seen. The main features of the fossil are described as follows.

Squamosal border and striae parietalis

Part of the squamosal border is preserved on the Shuidonggou parietal fossil (Figure 3, Figure 4). The length of the fossil along the squamosal border in the sagittal direction is 39.5 mm. The overlapping part of squamosal border is 11.0 mm long superoinferiorly. Above the squamosal border, some striae parietalis radiate perpendicular to the squamosal suture and extending posterosuperiorly for about 10.0 mm. The thin ridges between the striae parietalis are clear.

For the reason of incompleteness or poor preservation, striae parietalis were rarely described in fossil hominids. Weidenreich found that striae parietalis existed on all the parietals of *Homo erectus* from Zhoukoudian. The lengths of striae parietalis in Zhoukoudian vary (Weidenreich, 1943). Our observations of the casts of Zhoukoudian skulls I, II, III, and XII indicate that all the specimens have clear striae parietalis which are easily identified. The projection or the heights of the ridges exceed those of the Shuidonggou parietal. The striae parietalis in the Zhoukoudian specimens not

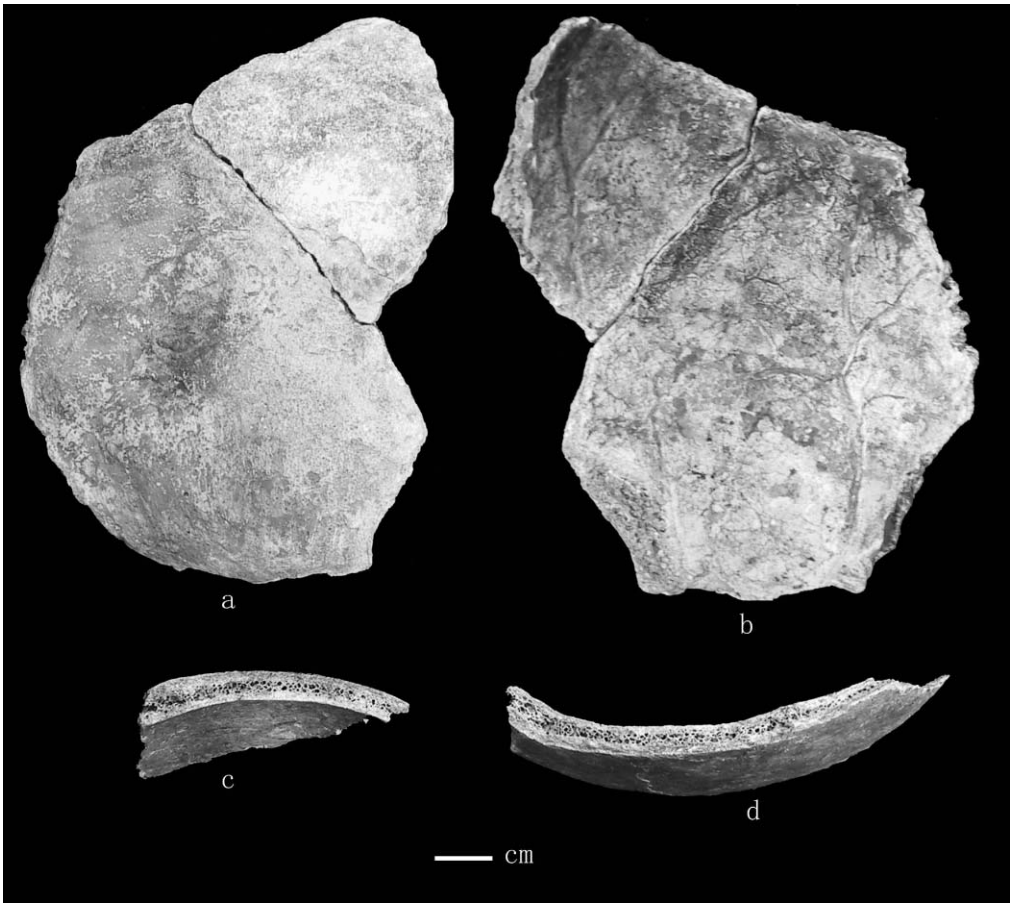

Figure 3. Fossil human parietal from the Shuidonggou site. a: external view. b: internal view. c and d: transverse sections of the adjacent two pieces.

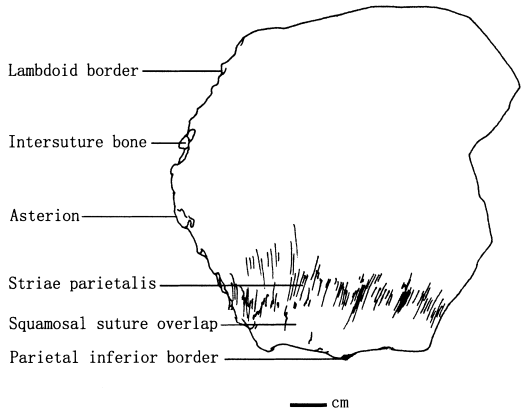

Figure 4. Shuidonggou hominid parietal, external view.

only exist in the overlapping area between the temporal and parietal, but extend superiorly above the squamosal suture. The length of the striae parietalis above the squamosal suture is about 7 mm.

The striae parietalis of *Australopithecus boisei* (OH 5 and KNM-ER 406) are located in the overlapping area of the temporal and parietals. The ridges between the striae parietalis are clear in these specimens. The distance between two adjoining ridges is 1.0 mm in OH 5 and KNM-ER 406 (Leakey et al., 1971; Rak, 1978; White, 2000).

The parietal fossil (BOD-VP-1/1) found at Bodo of Ethiopia, with the age of 600 ka (Clark et al., 1994), has obvious striae parietalis which is located in the overlapping area of the squamosal suture. The ridges between the striae parietalis are well developed. The striae parietalis length is 41.4 mm and maximum overlap is 28.3 mm in BOD-VP-1/1 (Asfaw, 1983). In Amerindian parietals, the overlapping area ranges from 8.8 to 21.0 mm and the striae parietalis lengths are 6.6 to 34.7 mm (Asfaw, 1983). In modern humans, striae parietalis are usually located above the squamosal suture. The overlapping area and striae lengths of the Shuidonggou parietal are towards the lower limits of the modern human ranges (Table 1). The ridges between the striae parietalis are more obvious in the Shuidonggou parietal than in modern humans, suggesting that the temporalis muscles were more strongly developed in the Shuidonggou fossil than in modern humans.

Mastoid border

The mastoid angle and the mastoid border are preserved in the Shuidonggou parietal. The length from asterion to the posterior end of the squamosal border is 24.5 mm, and the mastoid angle is 129.5º. The range of parietal-mastoid suture

length in Amerindians is 22.0 to 37.0 mm, and in modern north Chinese it is 14.9 to 29.2 mm. The mastoid angle ranges in modern north Chinese between 122.3º to 154.2º. The length of the mastoid border and the mastoid angle in the Shuidonggou parietal are within the ranges of variation seen in the Amerindian and modern north Chinese samples. The length of the mastoid border of the Bodo parietal is 39.2 mm and is greater than the average of modern humans. The mastoid angle in Bodo is 120º, which is less than the average of modern humans (Table 1).

The length of the parietal-mastoid suture in the Hexian *Homo erectus* cranium is 28.3 mm and its mastoid angle is 143.0º. These figures exceed the average values of modern humans and are close to the upper limits of the modern human ranges of variation. The corresponding data in the Upper Cave skull 102 are 23.8 mm and 143.0º, respectively. In the Ziyang skull, the length of the parietal-mastoid suture is 25.8 mm on the left and 22.3 mm on the right side. The mastoid angle on both sides is 123.1º and 126.0º, respectively. The two measurements in the Lijiang skull are 25.1 mm and 141.5º, respectively. All three skulls belong to late Pleistocene *Homo sapiens*, and the lengths of their parietal-mastoid suture are close to that of the Shuidonggou parietal. The mastoid angles in the three specimens vary but are within the modern human ranges of variation.

According to Asfaw's (1983) study, the parietal-mastoid sutures of modern humans are usually shorter, and the mastoid angles greater than in fossil hominids. However, as noted by Asfaw (1983), the mastoid angle and the parietal-mastoid suture length vary greatly in modern humans. Thus, these features cannot be regarded as a diagnostic character. Our observations of modern north Chinese and the above reference to the Chinese fossil materials also suggest large degrees of variation.

Lambdoid border

The length of the preserved lambdoid border of the Shuidonggou parietal is 42.1 mm externally from asterion. There is a small intersutural bone 14.9 mm from the mastoid angle. Starting at asterion the whole preserved lambdoid suture is serrated.

The length of the preserved lambdoid the border of the Bodo parietal is 46 mm externally from asterion. It becomes strongly serrated about 15 mm from asterion. In the Broken Hill parietal, the serration of the lambdoid suture begins 22 mm from asterion. The serration appears in the Ziyang parietal 19 mm from asterion. In modern north Chinese, the serrations usually begin 1 to 2 mm from asterion, but occasionally the lambdoid sutures change their straight line or microwave shape to serrations 10 to 30 mm from asterion. Therefore, it seems that the starting position of serration in the lambdoid suture has no fixed patterns.

Parietal thickness

The Shuidonggou parietal bone is thin. The thickness of the parietal squama of the Shuidonggou parietal is 4.8 mm at a point 50 mm from the inferior border. The maximum thickness at asterion is 5.9 mm. Both measurements are within the ranges of modern human variation (Table 1), and thickness at the parietal tuber and mastoid angle of the Shuidonggou parietal is 4.1 mm and 5.0 mm, respectively. These values are smaller than those of Neanderthals, archaic *Homo sapiens* found in Xujiayao, and Zhoukoudian *Homo erectus* (Table 2).

There is a little increase in parietal thickness from the parietal tuber towards the mastoid angle and asterion in the Shuidonggou parietal. But the increase is not so significant compared to the condition seen in the Bodo and Zhoukoudian specimens. In modern humans, there is no significant increase of thickness towards the lambdoid border. At a point 50 mm from asterion and the inferior border, parietal thickness is 8.0 mm in the Bodo specimen, and towards the lambdoid border the thickness increases to the maximum thickness of 20.8 mm at asterion. Zhoukoudian *Homo erectus* has average thickness of 10.0 mm at the parietal tuber and 14.8 mm at the mastoid angle. Thickness at the parietal tuber of some later *Homo sapiens* specimens found in Ordos (Wu, 1958), Harbin (Culture Relic Administration Office,

Table 1. Comparison of parietal measurements of the Shuidonggou specimen with those of modern humans and the Bodo

Specimens	Mastoid border length [a] (mm)	Mastoid angle [b] (º)	Parietal squamosal thickness [c] (mm)	Maximum asterionic thickness [d] (mm)	Parietal striation Length [e] (mm)	Squamosal suture overlap [f] (mm)
Shuidonggou [g]	24.5	129.5	4.8	5.9	10.0	11.0
Huabei [g] (n=32)	14.9-29.2	122.3-154.2	2.5-6.3	3.2-9.4	5.5-16.8	9.5-20.0
mean	21.8	138.5	4.6	5.9	11.0	13.5
Amerindian [h] (n=20)	22.0-37.0	-	2.0-7.0	5.8-11.9	6.6-34.7	8.8-21.0
mean	28.4	-	4.2	8.6	19.0	13.2
Bodo [h]	39.2	120.0	8.0	20.8	41.4	28.3

[a] Mastoid border length: measured from the ectocranial asterionic point to the most anterior point of the mastoid border.
[b] Mastoid angle: angle between the lambdoid and mastoid borders.
[c] Parietal squama thickness: vault thickness measured on the parietal squama at a point 50 mm from asterion and 50 mm from the inferior squamosal border.
[d] Maximum asterionic thickness: measured as a maximum thickness above asterion across the angular torus.
[e] Parietal striation length: measured from its inferior to superior terminus.
[f] Squamosal suture overlap: a maximum distance measured from the inferior squamosal suture edge to the overlap terminus, parallel to the striae axis.
[g] Present study.
[h] Cited from Asfaw (1983).

Table 2. Comparison of parietal thickness at the parietal tuber and mastoid angle (mm)

Location of measurement	Shuidonggou	Modern humans [a]	Neandertals [a]	Xujiayao [b]	Zhoukoudian *Homo erectus* [a]
Parietal tuber	4.1	2.0-5.0	6.0-11.0	7.0	5.0-16.0
mean		3.5	9.0		10.8 (n=7)
Mastoid angle	5.0	4.5-5.2	4.0-9.0	7.2	13.5-17.4
mean		4.9	7.3		14.8 (n=8)

[a] Cited from Weidenreich (1943).
[b] Cited from Jia et al. (1979).

Heilongjiang, 1990), Wushan (Xie et al.,1987) and Huanglong (Wang and Li, 1983) are 6.0 mm, 8.0 mm, 7.0 mm, and 8.5 mm, respectively. All of these thickness values are greater than that of the Shuidonggou parietal (4.1 mm). So, compared with late Pleistocene *Homo sapiens*, the Shuidonggou parietal is much thinner.

Middle meningeal artery

The internal surface of the Shuidonggou parietal is smooth and blood vessel grooves are very clear. The grooves of the posterior branch of the middle meningeal artery are easily seen (Figure 3b). The breadth of the grooves is narrow (about 1.0 mm) and there are many ramifications. The ramifications extend towards the lambdoid suture (Figure 5), which resemble the pattern seen in modern humans (Wu, 2003).

The middle meningeal artery of late Pleistocene *Homo sapiens* is moderate in groove breadth (about 1.5 mm), and has many ramifications. Its posterior branch extends to both lambdoid and upper parietal regions. The grooves of the middle meningeal artery in archaic *Homo sapiens* usually have moderate breadth, and the anterior branch extends towards the lambdoid and upper parietal regions, and the posterior branch extends towards the lambdoid region with fewer ramifications. In *Homo erectus*, the grooves of the middle meningeal artery are wide (about 2.0 mm) or moderate in breadth with the anterior branch running towards bregma and the posterior branch towards the lambdoid region. There are fewer ramifications.

Sigmoid sulcus

The inner surface around the mastoid angle of the Shuidonggou parietal is smooth and there is no visible sigmoid sulcus. In modern humans, the sigmoid sulcus usually extends onto the inner surface of the parietal at the mastoid angle area. The sigmoid sulcus of Zhoukoudian *Homo erectus* parietals also does not extend onto the parietals and just comes to the occipital and the mastoid of the temporal (Weidenreich, 1943). The Shuidonggou parietal does not have a sigmoid sulcus on its inner surface, which is different from most modern humans and similar to *Homo erectus* from Zhoukoudian.

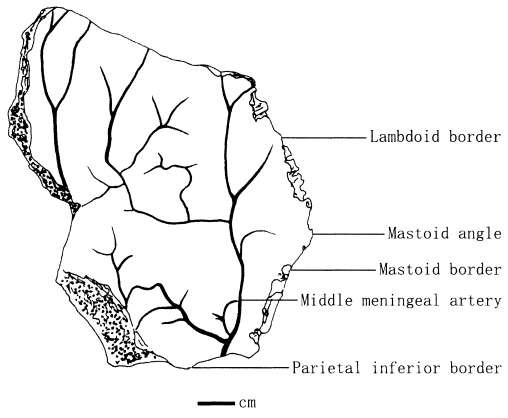

Figure 5. Shuidonggou hominid parietal, internal view.

The internal structure of the parietal

From the broken part of the Shuidonggou parietal, the internal structure of the Shuidonggou parietal is easily observed (Figure 3c, d). The Shuidonggou parietal is thin, and its outer and inner tables are dense in texture. The diploë is alveolate shaped. The whole bone is 5.0 mm thick with the outer table 2.1 mm, inner table 1.7mm, and diploë 1.2 mm, respectively.

The cranial vault bones of modern humans are thin with relatively thick and hard outer table and thin and fragile inner table. The development of the outer table, inner table and diploë is related with age. In children under 6, or adults older than 50, the three parts are not easily identified, but usually diploë thickness is less than or equal to the combined thickness of outer and inner tables. The internal structure of the Shuidonggou parietal is similar to that of modern humans. From its clear development of diploë we guess it represents a young individual.

The cranial vault bones of fossil hominids are usually thick. For example, the average thickness of Zhoukoudian *Homo erectus* cranial vault bones is 9.2 mm, with relatively thick outer and inner tables. In Neanderthals, the thicker part of the cranial vault bone is the diploë. The diploë of the Bodo parietal from Ethiopia is thick (8.5 mm) at a break superior to the angular torus. It is thicker than the outer and inner tables (2.0 mm). The thicker diploë extends to the lower part of the parietal toward the squamosal border. Diploë thickness of the Swamscombe parietal is close to that seen in Bodo, but the thick diploë does not extend inferiorly like it does in the Bodo specimen. In Swamscombe, at the lower part of the parietal toward the squamosal border, thickness of the outer and inner tables increases (Marston, 1937).

Others

In *Homo erectus* and other fossil hominids, an angular torus occurs at the mastoid angle at the end of the temporal lines. There is a supramastoid crest extension caused by the

bony thickening parallel to the angular tours which extends from the supramastoid crest of the temporal bone onto the parietal. Between the supramastoid crest extension and angular torus there is a sulcus named the supramastoid sulcus extension. All three features (angular torus, supramastoid crest extension and supramastoid sulcus extension) are strongly expressed on Zhoukoudian skulls I and VII, and the Bodo VP-1/1 parietal. The angular torus is usually weak or even nonexistent in modern humans. The supramastoid crest extension is occasionally seen in some of the most robust modern humans, and the supramastoid sulcus extension only exists in Middle Pleistocene hominids. The mastoid angle area of the Shuidonggou parietal is smooth with no bulging. There is no angular torus and the supramastoid crest extension is not observable.

Discussion and Conclusions

Shuidonggou is the earliest Upper Paleolithic site ever found and studied in China (Huang, 1989). The findings of stone artifacts with European Middle and Upper Paleolithic features have especially attracted the attention and interest of colleagues (Brantingham et al., 2001; Gao and Norton, 2001; Madsen et al., 2001). In addition, the estimated age of the site is late Pleistocene. So, the Shuidonggou site and its findings are of great value to the study of cultural evolution and population exchange in China and all of Northeast Asia. The human parietal studied in the present paper is the first human fossil ever discovered at the Shuidonggou site. Our observation and comparisons indicate that the expression of most features of the Shuidonggou parietal is within the range of variation of modern humans. Some features occurring on more archaic fossil hominids, like the angular torus, supramastoid crest extension, supramastoid sulcus extension and thick cranial vault bone, are not seen on the Shuidonggou parietal. The size (breadth and depth) of the middle meningeal artery impressions on the Shuidonggou parietal is also similar to that of modern humans. Putting all these findings into consideration, it is reasonable to believe that the Shuidonggou parietal mainly displays the morphological features of modern humans. On the other hand, this parietal exhibits certain degrees of fossilization, and there are at least two features unusual for modern humans. One is the ridges between the striae parietalis which are robust even though a little weaker than the condition seen in Zhoukoudian *Homo erectus*. This expression of striae parietalis suggests that the temporalis muscles of the Shuidonggou specimen were more strongly developed than in modern humans. The other feature different from most modern humans is the lack of the sigmoid sulcus at the mastoid angle of the Shuidonggou parietal. As mentioned above, the sigmoid sulcus lacking on the Zhoukoudian *Homo erectus* suggests that this is a primitive feature. So, on the Shuidonggou parietal, besides the numerous modern human features, there are still a few features similar to those of fossil hominids. Given that expression of many morphological features of the late Pleistocene or later *Homo sapiens* are expected to be very close to the modern human condition, just by depending on bone morphology itself, it is nearly impossible to determine the specimen's antiquity. However, according to the location of the fossil find and radiocarbon dates, the state of fossilization and contextual information of the Shuidonggou site, and the two primitive features of the fossil recognized above, we believe that it is likely that the Shuidonggou parietal comes from the late Pleistocene human population that lived in that area.

Acknowledgements

We wish to express our sincere thanks to Dr. Huang Weiwen and Dr. Gao Xing for valuable discussions. Our thanks also extend to Mr. Wang Huimin and Ms. Huang Jinling for their kind help for the site stratigraphy and figures. This study was supported by the Project from Ministry of Science and Technology of China (2001CCAO1700).

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